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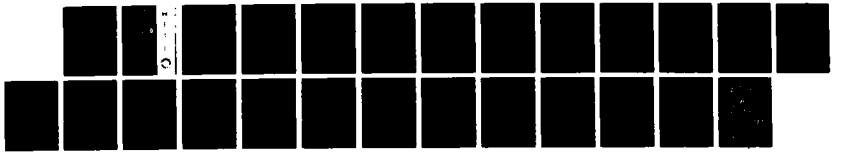

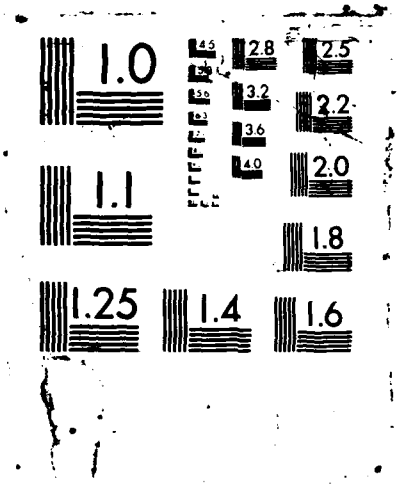
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A state-of-the-art assessment of automatic name placement

Herbert Freeman

Battelle Memorial Institute
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201-2693

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This report reviews the state-of-the-art of map name placement. A literature survey is provided of all the recent publications dealing with this topic. Some good-quality experimental systems are currently available; however, considerable further development is required before a fully automatic name placement system will be available that approaches the aesthetic quality obtainable from experienced manual placement.

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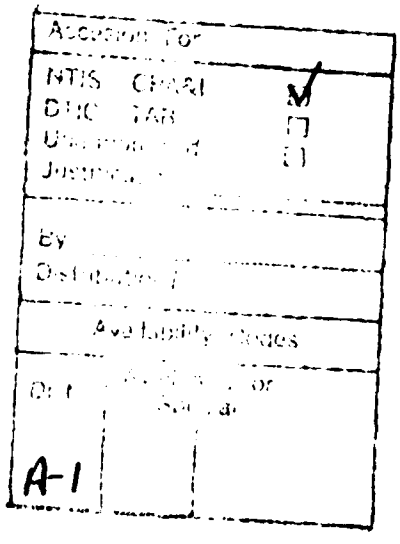

A State-of-the-Art Assessment of AUTOMATIC NAME PLACEMENT

1. INTRODUCTION

This report presents a state-of-the-art assessment of the *name placement problem* in computerized cartography. It is the result of a study made under a subcontract from Battelle Columbus Laboratories on behalf of the U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Virginia through the U.S. Army Research Office. It contains a comprehensive examination of the published literature on the subject of automatic map name placement, beginning with the 1972 article by P. Yoeli[1] which described the first definitive attempt at solving this problem. All known journal articles and books dealing with this subject during the period 1972-1985 were reviewed and a brief synopsis was generated for each. Some items are included which, although not directly dealing with name placement, have an indirect bearing on the subject. The synopses are presented in chronological order in Section 2 of this report. An overall assessment of the current state of the art of automatic name placement was prepared from the collected information and this is presented in Section 3. Section 4 contains the Conclusion. A comprehensive bibliography is given in Section 5.

[1]All literature items cited are listed in alphabetical order in Section 5, BIBLIOGRAPHY.

2. REVIEW OF THE LITERATURE

The following are brief synopses of the published literature on the subject of automatic name placement for the period 1972–1985, presented in chronological order.

1. Yoeli, P., "The logic of automated map lettering," *The Cartographic Journal*, 9, (2), December 1972, 99–108.

This is a thorough examination of the problem of automatic name placement. The author carefully examines every aspect of the problem and points out the sources of difficulty. The general rules for map name placement for point, line, and area features are reviewed; they are in accord with those enunciated by Imhof in 1962. Priorities of name placement are described. A method for automatic name placement is outlined. It is conjectured that fully automatic name placement should be possible. A system for name placement is proposed; however, no actual implementation is described. The article provides an excellent introduction to the computer name placement problem.

2. Keates, J.S., *Cartographic design and production*, Longman, London, 1973, (pp. 176–181).

This book contains a brief discussion of the name placement problem. Rules for placing point-, line-, and area-feature names are given. The problem of aligning names with grids and graticules is discussed. Also mentioned is the problem of placing names for polar maps and of interlacing point-feature names with spaced-out area-feature names.

3. Imhof, E., "Positioning names on maps," *The American Cartographer*, 2, (2), 1975, 128–144.

This article is a re-publication in English of the original German-language article published in 1962. It is a thorough and comprehensive study of the rules and conventions for (manually) placing names on a map. The author takes great pains in pointing out how careful positioning and aesthetics can facilitate the reading of a map. The rules for placement of point-, line-, and area-feature names are thoroughly explained, with ample illustrations. Different map projections are considered in light of their effect on name placement. The article does not address the particular problem of automatic name placement; nevertheless, because of the thoroughness with which it describes the various aspects of name placement, it should be considered a "must" for anyone interested in the automatic name placement problem.

4. Hirsch, S.A., *Algorithms for automatic name placement of point data*, Master's thesis, Department of Geography, State University of New York, Buffalo, New York, September 1980. 79p.

This master's thesis represents a serious attempt at achieving automatic name placement for point-feature names. Careful attention was given to implementation of the Imhof rules. Algorithms for point feature name placement were developed and programmed. The author included a number of illustrations of actual name placement for small-scale maps, and these were of relatively good quality. The main weakness of the work was the inability to have names curve with the parallels in the small-scale maps and the lack of any provision for handling linear-feature and areal-feature names. Also, it is this reviewer's belief that the actual placement procedures were relatively inefficient, and that this could lead to excessive computation requirements for a map with a large number of names.

5. Kelly, P. C., *Automated positioning of feature names on maps*, Master's Project, Department of Geography, State University of New York, Buffalo, NY, December 1980. 79p. plus program listing.

This master's thesis dealt with the problem of automatically positioning point feature name labels on a map. Although the author had hoped to deal with point-, line-, and area-feature names, he succeeded only in accomplishing point-feature name placement in a limited way. Considerable attention was given to the general aspects of the name placement problem, especially to label interaction, interference, and overlap with other labels or with features. The work provided a good starting point for later researchers.

6. Basoglu, U., "A new approach to automated name placement," *Proc. Auto-Carto V*, Crystal City, VA, August 1982, pp. 103-112.

This paper describes the initial stages of a project to develop an automatic map name placement system. The author carefully delineates the problem, points to the sources of difficulty, and recognizes the existence of fully-automated, semi-automated, and interactive name placement approaches. The paper describes an attempt at creating a comprehensive data base, suitable for automatic name placement, from digital line graph (DLG) files and GNIS name files. The problem is a difficult one because there is no direct association between names from the GNIS files with features in the DLG files. The creation of a comprehensive data base for linear-feature names was found to be virtually impossible because only one coordinate at the mouth of each river is included in GNIS. Some success was obtained by using the

names from the 1:2,000,000 scale file to extract coordinates from corresponding 1:24,000 scale GNIS files. Areal names processing was less successful because of difficulties of associating names from the GNIS files with the areal polygons from the DLG files. A method was described for ranking names so that a decision can be made as to which names to include in a map when excessive clutter is to be avoided. The work represents an important contribution to creating a comprehensive data base from presently available files, a preprocessing task required before automatic name placement can be achieved.

7. Hirsch, S.A., and Glick, B.J., "Design issues for an intelligent names processing system," *Proc. Auto-Carto V*, Crystal City, VA, August 1982, pp. 337-346.

This paper addresses the problem of automatic names placement. The overall problem is recognized as consisting of three phases: (1) the selective retrieval of names and spatial data, (2) the positioning of the names amidst the spatial data, and (3) the actual display or plotting of the final labeled product. Some methods for possible feature-name placement are described. The opinion is expressed that the technology has advanced to a point where all the necessary tools are now available and that automatic name placement should be seriously considered. There is no mention of any actual attempt at implementing an automatic name placement system. The paper provides good background for anyone contemplating the design of a name placement system.

8. Payne, R.L., "Geographic names information system: an automated procedure of data verification," *Proc. Auto-Carto V*, Crystal City, VA, August 1982, pp. 575-580.

The Geographic Names Information System (GNIS) of the U.S. Geological Survey is described. The system is a multipurpose data system designed to meet a variety of cartographic needs. The development of the GNIS is described, including the collection of names, the verification of collected data, and the display of the data. Considerable attention is devoted to the data verification problem. Unfortunately, the paper does not include any details on the actual data organization used in GNIS. An interesting method was employed to check for overprinting of names. Each area around a name within $\pm$ 2 seconds of latitude and 15 seconds of longitude was tested for overprinting. Where overprinting was detected, one of the names was moved by $\pm$ 3 seconds in latitude. No shift was made in the feature location. A stated objective of the work is to develop a names data base that can ultimately be used in an automatic names placement system.

9. Goldberg, J.L., and Miller, T.C., "Interactive name placement for provisional maps," *Proc. 43rd Annual Meeting of the American Congress on Surveying and Mapping*, Washington, DC, March 1983, pp. 314–321.

The authors describe a graphics design system for interactive name placement. Software was developed to aid an operator in the placement of map lettering. The system was designed to accommodate large-scale, medium-scale and small-scale maps. A procedure was included that permits an operator to place a name along a curve, where the curve is defined by three points. The problem of automatic name placement was not considered.

10. Freeman, H., "Map data processing and the annotation problem," *Proc. 3rd Scandinavian Conference on Image Analysis*, Chartwell-Bratt Ltd., Copenhagen, Denmark, July 1983.

This paper begins with a general introduction to the problems of map data processing and then focuses in on the name placement problem as one that is particularly deserving of attention at this time. The various aspects of point-feature, line-feature, and area-feature name placement are examined. Primary attention is devoted to area-feature name placement because of its complexity. The work described represents the initial stages of a long-term effort to develop an automatic name placement system.

11 Balodis, M., "Positioning of typography on maps," *Proc. ACSM Fall Convention*, Salt Lake City, Utah, Sept. 1983, pp. 28–44.

This article deals with the selection of typography for maps. It describes psycho-visual experiments with groups of individuals to determine whether the choice of font or the type of placement, i.e., rectilinear or sinusoidal, or parallel or dispersed, would have any effect on the time required to locate a chosen name (search time). Generally, the author's test show that there is no significant difference in readability nor in speed of association between feature and name. The conclusion is that simple, straight name positioning (as in an engineering drawing) may be fully satisfactory. Also, there appears to be little advantage to the use of many different type faces. The results suggest that some of the traditional approaches to map lettering may be simplified without compromising map readability. This may have an important impact on automatic map name placement. The results are, however, not necessarily at variance with those of Eastman [1985] and the need for further studies may be indicated here.

12. Ahn, J., and Freeman, H., "A program for automatic name placement," *Proc. AUTO-CARTO SIX*, Ottawa, Canada, October 1983,

A computer program is described that will automatically place names for area-, point-, and line-feature names in a map. Careful attention is given to established rules for name placement. An algorithm is described for achieving good-quality area-feature name placement. The algorithm extracts the skeleton of the area feature, reduces the skeleton to a dominant curve, and then uses this curve as the baseline for the feature name. The results are generally good; however, in a few cases the result is less than satisfactory. The algorithms for point-feature and line-feature name placement appear to be more robust. Although the intent was to develop a fully automatic name placement system, the authors recommend that a post-editor be available for manually making any necessary placement corrections in the final product.

13. Payne, Roger L., "Geographic names information system," *USGS Digital Cartographic Standards*, Geological Survey Circular 895-F, Distribution Branch, Text Products Section, U.S. Geological Survey, 604 South Pickett Street, Alexandria, VA 22304, 1983.

This publication is a chapter from a larger publication which is concerned with digital cartographic data standards in use within the USGS and the efforts of the USGS to establish new digital cartographic data standards. This chapter deals specifically with the Geographic Names Information System (GNIS) used for managing names and related information digitized from maps and records of the USGS and other sources. There are five data bases in GNIS: (1) National Geographic Names Data Base, (2) USGS Topographic Map Names Data Base, (3) Generic Data Base, (4) National Atlas Data Base, and (5) Board on Geographic Names Data Base. A detailed description is given of the structure of each of the data bases used. Four appendices are included, containing, respectively, a list of the named features not yet included in GNIS, the GNIS feature class definitions, a list of parenthetical descriptors used with names, and a selection of sample records from GNIS.

14. Ahn, J., *Automatic map name placement system*, doctoral dissertation, Rensselaer Polytechnic Institute, Troy, NY 12181, May 1984. (Also available as Tech. Rept. IPL-TR-063.)

This is a doctoral dissertation describing an intensive research effort to achieve automatic map name placement. The author first reviews the problem of name placement and then proceeds to develop a variety of algorithms for achieving placement of area-, point-, and line-feature names, in that order. Precedence rules are developed to form a hierarchy for applying names placement rules. The medial-axis transform (skeleton method) is applied to arrive at a baseline for area-feature names placement. A curvature analysis algorithm is utilized to permit names to follow the curvings of

linear features. Overlap among names and between names and point features is avoided by means of a heuristic state-space search that attempts to minimize the required movement of names. The author's strong background in computer graphics and artificial intelligence is apparent through the extensive use of sophisticated algorithms and data structure techniques. The entire system follows a rule-based expert-system approach, making addition, replacement, or deletion of a placement rule relatively simple. The author's stated objective was to achieve fully automatic names placement. Good results were achieved, especially with respect to placement of area-feature names and the combined (interlaced) placement of area-feature, point-feature, and line-feature names.

15. Freeman, H., and Ahn, J., "A system for automatic name placement," *Proc. 4th Jerusalem Conference on Information Technology*, IEEE Computer Society, May 1984, pp. 134–143.

This paper describes the results of a research investigation in automatic names placement and is largely based on the doctoral research of one of the authors (Ahn). The rules for name placement of area-, line-, and point-feature name placement are reviewed in light of an automatic names placement project. A description is given of the skeleton approach to finding the baseline for area-feature names placement. The procedure for selecting point-feature names placement is described in detail, including a procedure for heuristically searching a graph of permissible-position locations. Some sample maps are included which show an improved quality level over those shown in the authors' earlier publications.

16. Basoglu, U., *A new approach to automated name placement*, doctoral dissertation, Department of Geography, University of Wisconsin, Madison, WI, 1984.

This is a doctoral dissertation describing the author's research in automatic name placement. The goal of the work was total automation of name placement and the achievement of a lettering quality that was functional and readable, and would be an improvement over strictly mechanical-looking lettering. The research included the creation of a names data base, development of algorithms for point-feature name selection, size-scale relationships for type sizes, and placement algorithms for point-, line-, and area-feature names. The report devotes a considerable amount of space to the selection of type styles and sizes. Examples of name placement are provided. Generally the quality of point-feature name placement was high, except that for small-scale maps, the names were not curved to parallel the constant-latitute lines (as was done by Ahn [1984], for example). Line-feature name placement was of good quality in some instances but quite unsatisfactory in others. Relatively little was done with area-feature name

placement. The paper indicates an awareness of both the accomplishments and shortcomings of the research described and suggests avenues for future research. The author raises the question whether it is indeed necessary to achieve the same level of quality with automatic name placement as that achievable with manual placement. The work represents an important milestone on the road to eventual fully automatic map names placement.

17. Freeman, H., and Ahn, J., "AUTONAP – an expert system for automatic name placement," *Proc. Int'l. Symposium on Spatial Data Handling*, Zurich, Switzerland, August 1984, pp. 544–569.

This paper is a follow-up to earlier work by the authors and shows an increased awareness of the subtleties of achieving high-quality map lettering and names placement. The authors have dedicated themselves to obtaining a map lettering quality that is eventually near-equal to that available from manual lettering. Special attention is given to the placement of area-feature names so that the names will reflect the dominant shape and extent of the areas. For small-scale maps, horizontally placed names are curved in accordance with the parallels. The software system described by the authors, AUTONAP, is designed as an expert system which embodies in it the rules used by expert cartographers in manual names placement. The paper includes a listing of the placement rules included in AUTONAP. Implementation is via the FORTRAN language (rather than, say, LISP) to achieve portability and performance.

18. Brassel, K.E., Heller, M., and Jones, P.L., "The construction of bisector skeletons for polygonal networks," *Proc. International Symposium on Spatial Data Handling*, Zurich, Switzerland, August 1984, pp. 117–125.

This paper introduces the concept of bisector skeletons, which represent a variation on the traditional skeleton or medial-axis transform of a polygonal region. The bisector skeleton differs from the conventional skeleton in that the propagation wave consists of extended elements that are all linear and perpendicular to the polygon edges. It is a tree structure for simply connected polygons, and a graph for multiply connected polygons. Its edges are the loci of all points equally distant and closest to a pair of polygon edges; a skeleton point is a point of equally distant from three polygon edges. The bisector skeleton is a new data structure form for polyhedral data that appears to have distinct advantages for certain cartographic data. Relative to the name placement problem, the bisector skeleton may facilitate finding the optimum baseline for placement of an area-feature name.

19. Payne, R.L., *Geographic names information system users guide*, Department of the Interior, U.S. Geological Survey, Open File Report 84-551, 1984.

This report describes the Geographic Names Information System (GNIS) developed at the USGS. The system contains five data bases that provide information on approximately 2,000,000 geographic names in the U.S. Each of the data bases is described in terms of its labels and data elements. Also included is a data management system and lists of rules for accessing, searching, and retrieving information from the data bases. An extensive set of appendices with detailed information and examples of GNIS is also provided. GNIS is, of course, the most likely source of names information for any automatic name placement system in the U.S..

20. Lacroix, V., "An improved area-feature name placement," Tech. Rept. IPL-TR-064, Image Processing Lab., Rensselaer Polytechnic Institute, Troy, NY 12181, October 1984.

This master's thesis describes a research investigation for achieving high-quality area-feature names placement. Two algorithms are developed which attempt to improve on the skeletonization approach to finding the optimum baseline for area-feature name placement. One is used for horizontal name placement (i.e., placement parallel to the constant-latitude lines) and another for those area features for which horizontal placement is not appropriate. It could not be established whether the results will always be superior to those obtainable form the skeleton approach. In any case, it presents alternate placement strategies which can be called upon when the skeleton approach does not yield a satisfactory result. Some of the sample results shown are of remarkably good quality. Point- and line-feature name placement was not considered.

21. Cromley, R.G., "An LP relaxation procedure for annotating point features using interactive graphics," *Proc. AUTO-CARTO 7*, Washington, DC, March 1985, 127-132.

The author of this paper has attempted to apply mathematical programming techniques to the name placement problem. Specifically, an effort was made to use linear programming to solve for the optimal placement of point-feature names. Placing names is subject to a host of constraints, and the use of linear programming with an appropriate cost function should help determine an optimum placement (i.e., one that minimizes the "cost"). The paper did not contain any illustrations of actual name placement. The approach is interesting but of questionable practical value. Linear programming solutions tend to be computationally expensive, and the benefit over more straight-forward graph searching is questionable. Only point-feature name

placement was investigated. In a recent conversation with the author, the reviewer was told that no further work in this area was planned.

22. Pfefferkorn, C., Burr, D., Harrison, D., Heckman, B., Oresky, C., and Rothermel, J., "ACES: a cartographic expert system," *Proc. AUTO-CARTO 7*, Washington, DC, March 1985, 399-407.

The authors describe an expert system for name placement. The system uses an artificial intelligence approach in an attempt to capture the expertise used by cartographers in labeling maps. Point-, line-, and area-feature name placement is considered. A general procedural knowledge base is is employed to contain the name placement rules. The work is closely based on that of Ahn and Freeman [1983] which the authors cite. The order of name placement is area feature, point feature, and then line feature, as also used by others. The authors mention the possibility of using skeletonization for area-feature name placement; however, the one illustration included in the paper apparently did not use that technique. The purpose of the research appears to have been more exploratory, to determine the suitability of the expert systems approach to cartographic tasks, rather than to develop a working automatic name placement system.

23. Robinson, G., "Expert systems in map design," *Proc. AUTO-CARTO 7*, Washington, DC, March 1985, 430-439.

The author proposes the use of the expert system approach as an aid to the map designer. A brief description is given of the expert system concept. Various areas of potential application of expert systems in cartography are identified. However, the problem of expert system name placement is not specifically addressed.

24. Roubal, J., and Poiker, T.K., "Automated contour labelling and the contour tree," *Proc. AUTO-CARTO 7*, Washington, DC, March 1985, 472-481.

This paper is concerned with the logical representation of contour lines and the correct labeling of contour lines even though the lines may have gaps or may close outside the map boundary. A computer procedure is defined which permits scanning a contour map and recognizing the spatial relationships existing among the lines. Emphasis is placed on the contour line structure and label assignment. The problem of name placement for contour lines is not considered.

25. Eastman, J. R., "Names placement and positional recall of map information," *Proc. ACSM*, Washington, DC, March 1985, 474-482.

The author describes an investigation into the role that careful name placement plays in achieving proper association between a feature and its name. It is concluded from a series of experiments that good placement is indeed a powerful aid in assuring unambiguous and rapid association. Furthermore, the experiments also confirmed that the location of a point feature is remembered more by the location of its name than by the location of its feature symbol. The results reinforce the belief that careful name placement is a powerful factor in achieving a map of high effectiveness for the map user (and argue against the conjecture of Basoglu [1984] that high aesthetic quality in name placement may be an unnecessary luxury).

26. Freeman, H., "The automatic labeling of geographic maps - a problem in computer aesthetics," *Proc. Graphics Interface 84*, Montreal, Quebec, Canada, May 1985.

This paper describes the AUTONAP system, an expert system for automatic names placement developed by the author and his associates. Particular emphasis is placed on achieving high aesthetic quality of lettering, that is, lettering comparable in quality to what an experienced cartographer would produce. Much of the content of the paper is similar to what the author and his associates have previously published. A new refinement, not previously disclosed, deals with the aesthetic interaction of names in adjacent areas. This is a kind of "clashing" phenomenon, where two names, fully satisfactory in appearance individually, aesthetically clash to produce a disturbing effect when in close proximity to each other.

27. Doerschler, J., *Map data production for an expert name placement system*, Tech. Rept. IPL-TR-073, Image Processing Laboratory, Rensselaer Polytechnic Institute, Troy, NY 12181, May 1985.

The author describes in detail the design of a database for a name placement system, together with various software tools for building such a database. The software tools described are concerned with the entry of digitized map data, with data merging, with editing and naming of data, and with output plotting. No discussion of actual name placement is included.

28. Freeman, H., "Development of an automatic geographic map name placement system," *Proc. 4th Scandinavian Conference on Image Analysis*, Tapir, Trondheim, Norway, June 1985, pp. 617-628.

This is a follow-up on earlier publications by the author and his associates concerning the development of a fully automatic system for placing area-, point-, and line-feature names. The system is in the nature of an expert system, in which the name placement rules are embedded in an explicit rule

base. Particular attention is devoted to the generation of name placement of high aesthetic quality.

29. Doerschler, J., *Data structures required for overlap detection in an expert map name placement system*, Tech. Rept. IPL-TR-077, Image Processing Laboratory, Rensselaer Polytechnic Institute, Troy, NY 12181, August 1985.

In this report the author describes his extensive efforts to develop an effective database that will facilitate automatic map name placement. The report represents a continuation of an earlier report [1985] and provides detailed information on the kinds of data files used, the representation of point, line, and area data, the handling of overlap and clipping, the use of k-d trees for efficient graph searching, and other aspects of the data structure. The work is part of an on-going effort to develop a full-feature automatic name placement system that will be able to handle high-density name placement for both large-scale as well as small-scale maps.

30. Heard, A., *A manual for AUTONAP*, Image Processing Laboratory, Rensselaer Polytechnic Institute, Troy, NY 12181, August 1985. (Unpublished report; limited-distribution copies available on request from reviewer.)

Documentation is provided for the use of the current version of AUTONAP, an automatic map name placement system. Installation information is given, with particular attention to possible RATFOR and system incompatibility problems. The parameters to be assigned by the user are identified and explained. Information is provided concerning the plotting of output files. Also included is some general information on modifying AUTONAP. Six appendicies are included, providing various cross-reference information as well as a list of the AUTONAP source files and key subroutines.

31. Nastelin, J., *Optimization of baseline determination for area map annotation*, Tech. Rept. IPL-TR-078, Image Processing Laboratory, Rensselaer Polytechnic Institute, Troy, NY 12181, August 1985.

Of the three kinds of feature names, area-feature names are without doubt the most difficult to place properly with any kind of automatic placement system. The author reviews the various schemes for area-feature name placement and then proposes a multi-algorithm approach. In this approach, a placement algorithm is applied and the result evaluated. If the result is satisfactory, no further action is taken. If not satisfactory, another algorithm is tried, etc. The algorithms are applied in order of relative complexity. In effect, we have here a kind of feedback approach in which different algorithms are tried until a satisfactory one is found. The underlying philosophy of the approach is that it is easier to evaluate a

particular placement for its quality than *a priori* to select an algorithm that will provide satisfactory placement for a particular-shaped area feature.

3. STATE OF THE ART

The primary objective of this report is to make an assessment of the current state of the art of automatic name placement. A careful study of the published literature concerned with automatic names placement was made and numerous discussions were held with individuals who have been active in this area. The results of this study are presented here.

Although Yoeli in 1972 already had developed a simple automatic name placement system, there were no further significant efforts toward automation of the map name placement problem until Hirsch [1980] and Kelly [1980] took a new look at the problem. We are distinguishing here between what might be called "mechanical lettering" systems, in which names are placed in a manner that resembles the lettering on an engineering drawing, and systems that attempt to achieve a style that approximates that of experienced cartographers. Only the latter are under discussion here.

There is now general agreement that there are no basic technological obstacles to achieving fully automatic name placement of high quality, and that all that remains to accomplish it is an intensive R & D effort. A question is raised by some precisely as to what level of aesthetic quality is required. Some, such as Balodis [1983] and Barsoglu [1984], express the opinion that the rules postulated by Imhof [1975] are overly severe and, in fact, not necessary to produce maps of high effectiveness. Others, such as Eastman [1985], point to studies that show that feature association and positional recall are greatly enhanced by strict adherence to the Imhof rules. This reviewer tends to side with Eastman in the belief that high aesthetic quality is of direct functional value in enhancing the effectiveness of a map as a communication medium, and that every effort should be made to approach the level of quality now routinely expected from experienced cartographers.

In considering the development of an automatic name placement system, we must recognize that it may not be possible to achieve the equivalent of human performance in all instances. This raises the question as to whether some semi-automatic system may be preferable. Clearly, there can be different degrees of semi-automatic performance. At one extreme is an interactive system with strong computer assistance, something that could be called a "computer-aided name placement system." At the other extreme is the fully automatic system with a post editor; the post editor is used to make those placements that the automatic system was unable to carry out or to correct those where placement is less than satisfactory. It would appear that the goal should continue to be fully automatic name placement, with the recognition that a post editor may, nevertheless, be required for a small number of cases. The post editor should have extensive built-in

computer-assistance capabilities to permit rapid manual corrections by only moderately skilled personnel.

Since the late 1970's the USGS has been involved in the development of a comprehensive map name information system, GNIS. Any automatic name placement system should be able to utilize data directly from digital line graph (DLG) files and from the appropriate GNIS data base in the generation of a map product. Some efforts along those line have been made by Barsoglu [1982] but with only mixed results. A new research study directed specifically to linking GNIS and DLG data is another task under the present contract; at this stage indications are that such linking is feasible but that an extensive software development effort will be required before it can be achieved.

Efforts to date for automatic names placement have generally concentrated on small-scale maps, say, 1:500,000 or smaller. This is probably the scale at which the highest name density is normally encountered and which should present the greatest difficulties. Fairly good placement has been achieved for point-feature names, and the problems of achieving unambiguous association and avoiding overlap appear fairly well under control. Some difficulty is still being experienced with some of the more subtle rules, such as requiring that a point feature that lies to one side of a linear feature should have its name placed to the same side, and that point features on a coastline should have their names placed "in the water." Ahn [1984] was able to satisfy these rules in many cases but his method was not able to cope with all the possible situations. Barsoglu [1984] and Pfefferkorn [1985] were able to achieve generally good point-feature names placement; however, neither attempted to have names in small-scale maps parallel the constant-latitude lines, as was done by Ahn.

Fairly good linear-feature names placement was achieved by both Ahn and Barsoglu. Pfefferkorn succeeded in placing route numbers on highways. Generally, the problem of linear-feature name placement appears to be the most tractable, mainly because there is the most freedom as to the name location. Some difficulties may occur where a number of linear features closely parallel each other and leave no room for unambiguous name placement. This may require moving a feature, a task that for the time being is probably best left for manual post editing.

Area-name feature name placement has been intensively addressed only by the Freeman group. Imhof [1975] already recognized that area-feature name placement presents the greatest challenge to a cartographer. A variety of promising algorithms have been developed by Ahn [1984], Lacroix [1984], and Nastelin [1985], all of the Freeman group. The approach currently favored is to use what has become known as the "feedback"

approach, where a number of algorithms are tried in sequence until a satisfactory result is obtained. In effect, this shifts the burden of algorithm selection on an *evaluation algorithm* which examines a particular placement and decides whether or not the placement is acceptable.

Ahn [1984] decided to follow the suggestion of Imhof [1975] to have placement proceed in the order (1) area features, (2) point features, and (3) line features, with backtracking permitted if placement in one category suggested revision in placement of a name in a previous category. This approach appears to be sound, as borne out by considerable experimentation.

Thus far, most placement efforts have used maps with relatively sparse name densities. It is not clear how some of the automatic placement techniques will fare in situations of very high name density. An effort to explore this is under way by Doerschler [1985].

In general it appears that there is no great difficulty of achieving automatic name placement that provides unambiguous association between feature and name, avoids overlap among names and between names and point features, and yields results of satisfactory readability. Most of the difficulty at this time is concerned with achieving a higher level of aesthetic quality. Although there is some minor disagreement on this question, it is generally conceded (and borne out by experiments, Eastman [1985]) that high aesthetic quality improves perception of a feature's character, increases the speed of association, and enhances positional recall. The difficulties here, however, do not appear insurmountable in light of the impressive results that have already been achieved.

There are some aspects of the name placement problem that have similarity with those of the map generalization problem: under certain conditions satisfactory name placement is only possible if one or more features are moved. This problem, which an experienced cartographer can handle relatively easily, is particularly difficult for an automatic system. Some efforts along these lines are presently being carried out[2]; however, this task may have to be relegated to manual post editing for the foreseeable future.

Relatively little attention has been given by any of the researchers to the question of performance. Maps typically involve a very large amount of data and the cost of name placement may be a significant part of the production process. At this stage in the development it is probably correct not to be too concerned about the performance question. Indications thus far are that placement will be computation-intensive but not exorbitant.

[2]Work under NSF Grant ENG 8407900 to Rutgers University, New Brunswick, NJ 08903. H. Freeman, Principal Investigator.

With the cost of computation steadily going down, performance should not be a significant concern in the long term.

At the present time there are no known name-placement software systems on the market that are capable of producing a quality approaching that of an experienced cartographer. Nevertheless, on the basis of demonstrated research achievements it would appear that such packages are within reach and are only awaiting an intensive R & D effort.

Of the efforts at developing an automatic names placement system in recent years, those of Barsoglu, Pfefferkorn, and the Freeman group have been the most significant. From conversations with Barsoglu and Pfefferkorn, neither appears to be active in continuing his earlier work. Thus it appears that only the Freeman group is carrying out an active research effort in this area at present. Their effort is directed toward fully automatic name placement, with particular emphasis on achieving high aesthetic quality.

4. CONCLUSIONS

This assessment of the state of the art of automatic name placement appears to show that fully automatic name placement, although currently not available, is well within reach and is only awaiting an intensive R & D effort to bring it to fruition. The automatic system should be able to handle all feature-name placement, from a scale of 1:24,000 to one of 1:5,000,000, and for a very high percentage of the names, the quality of the placements should meet all present standards. An interactive post editor, which utilizes some of the same software routines contained in the automatic system, could then be called upon to raise the quality level of any substandard placements to an acceptable level. One should, however, not underestimate the development effort still required before a production-quality software system would be available, as a considerable amount of R & D work is still required.

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